V−03.01 General

V−03.01.1 Design Guidance

For a general discussion of guidelines for storm drainage, the designer is referred to the publication, "Highway Drainage Guidelines," published by the American Association of State Highway and Transportation Officials, (AASHTO). For more design and engineering guidance refer to the Federal Highway Administration Publication, "**Urban Drainage Design Manual,**" (HEC No. 22).

Some communities have adopted Storm Water Design Manuals or Master Plans. When designing in these communities, the local criteria should be followed, in addition to NDDOT criteria. Conflicts should be addressed as early as possible in the hydraulic study. If possible, major conflicts or concerns for cost sharing should be decided in the concept phase of the project.

V−03.01.2 General Design Considerations

Urban roadway design requires the grade line to be lower than the adjacent properties. Therefore runoff from the adjacent land is received over the top of curb and gutters and intercepted in inlets. Inlets are connected to lead lines which carry the flow to manholes, a larger trunk line, and ultimately to the outfall location.

Some general guidelines governing the storm drain system are as follows:

1. Storm drain systems shall be designed in accordance with the "Highway Classification Criteria - Design Flood Frequency" (Appendix V−01A)

2. Where critical traffic flow or adjacent facilities are involved, higher than standard design frequencies should be considered. (See Risk Assessment under Design Frequency-Section V-01.03.4).

3. Wherever possible, trunk lines should be located behind curb and gutters.

4. Wherever trunk lines are located under roadways, manhole castings should be located in the center of traffic lanes. The purpose is to reduce the chance of wheels striking the manhole castings.

5. As a rule of thumb, manhole spacing should be limited to a maximum of 400 feet.

V−03.02 Design Parameters

V–03.02.1 Computing Runoff (Rational Method)

The first step to be considered in the design of an urban storm drainage system is the determination of the runoff. The Rational Method, as described in Section V–0I.04 is the method that applies to the vast majority of watersheds that are to be handled by storm drains.

Four components make up the empirical formula of the rational method for computing discharges. The formula is:

$$\mathbf{Q = CIA}$$

1. Q = maximum design rate of runoff, cfs.

2. C = runoff coefficient representing a ratio of runoff to rainfall (Appendix V–03A).

3. I = average rainfall intensity for a duration equal to the time of concentration, for a selected return period, in/hr (Appendix V–03C).

4. A = drainage area tributary to the design location, acres.

The results of using the rational formula to estimate peak discharges is very sensitive to the parameters that are used. The designer must use good engineering judgment in estimating values that are used in the method.

V–03.02.2 Time of Concentration

The time of concentration is the time required for water to flow from the most remote point of the drainage area to the point of interest. Use of the rational formula requires the time of concentration for each design point within the drainage basin. The duration of rainfall is then set equal to the time of concentration and is used to estimate the design average rainfall intensity (I).

For a specific drainage basin, the time of concentration consists of an inlet time plus the time of flow in a closed conduit or open channel to the design point. Inlet time is the time required for runoff to flow over the surface to nearest inlet and is primarily a function of the length of overland flow, the slope of the drainage basin, and surface cover. Pipe or open channel flow time can be estimated from the hydraulic properties of the conduit or channel. In all cases the time of concentration shall not be less than 5 minutes. An alternative way to estimate the overland flow time is to use Figure 2 in Appendix V–03B.

V–03.02.3 Drainage Areas (A)

Generally, the following stratagem may be used in determining the drainage areas:

- Data Terrain Models (DTM's)

  Watershed areas for urban drainage studies can be delineated from data terrain models that have been developed from surveys conducted by the 'Surveys' section of the Design Division. These surveys are performed on all federally funded projects according to the time frame set by 'Milestone', which is usually six months to one year in advance of design. The coverages for the surveys are limited to the project corridor and are usually inadequate alone to compute the drainage areas. The value of the DTM's is that the coverage allows for 3-dimensional evaluation using the state of the art software for this purpose. The software used by the NDDOT is a civil design type known as 'Geopak' coupled with a drafting package 'Microstation'.

- USGS Maps

  These maps are contour maps developed by the US Geological Survey and are available through the North Dakota Geological Survey office in Bismarck. They are also available by calling US Maps at 1–800–275–8747. Original maps or copies can also be obtained through the State Water Commission and the NDDOT on the Capitol Grounds in Bismarck. Another source to access the maps is through the software known as 'Arcview'. The maps are essential to supplement the DTM's mentioned above.

- Photography

  Projects designed by the NDDOT are aerially photographed by the 'Survey' section of the Design Division. After the photographs are developed, they are catalogued, and stored within the 'Photography' section of the Information Technology Division of the NDDOT.

- On-Site Inspection

  Once delineation of drainage areas has been performed, the on-site review is conducted to verify drainage boundaries. This usually is accompanied with ground photos to be filed with the drainage study report.

V–03.02.4 Rainfall Intensity (I)

Rainfall Intensity Duration Frequency (IDF) curves have been developed through a system, known as HYDRAIN which covers the entire country.

IDF curves can be accessed for any city or location under this software. The only requirement is to know the latitude and longitude of the site location. The report will give the major time and intensity coordinates for the graph. Any points between have to be interpolated.

The curves used by the NDDOT have been refined by using formulas to bridge the major points of the graph. This process has been developed within the Design Division of the NDDOT. The curves in Appendix V‒03C reflect the refinements for the 13 major cities of North Dakota.

V‒03.02.5 Runoff Coefficients (C)

Runoff coefficients are shown in Appendix V‒03A. It should be emphasized that the proper selection of the (c) value is quite important. With the use of Geopak software and the DTM's, one can better analyze the permeability of any given area.

The values within this Appendix give general as well as specific recommended values. In the final analysis, the engineer doing the study should use their judgment for the selection.

V‒03.02.6 Discharge (Q)

Discharges computed using the Rational Method are 'peak' discharges. These flows then are the result of the three components listed above (C,I.&A). It can be seen the importance of spending some time to develop the best judged values for each. Varying just a little in the (C) selection or the (I) component can greatly affect the size of the storm drain and therefore the cost of the system.

V‒03.02.7 Design Frequency and Spread

Frequency

A design frequency should be selected commensurate with facilities cost, potential flood hazard to property, expected level of service (functional classification of highway or urban program), political considerations, and budget constraints.

See Appendix V‒01A for **Highway Classification Criteria - Design Flood Frequency.** In addition to that Appendix, refer to the '**Functional Classification and Urban Program Maps**' for North Dakota's 13 major cities. These maps may be found in Section I‒04 of this manual or may be obtained from the Planning Division of the North Dakota Department of Transportation.

Design Spread

Allowable spread width should be calculated, (HEC 12), for no less than a 10 year design frequency. The width of the water surface (spread) should not exceed the following criteria:

- On a two-lane roadway without a parking lane, the spread should be limited to the shoulder width plus the width of one-half of the driving lane.

- On a two-lane roadway when a parking lane is provided (minimum 8 foot wide), the spread should be limited to the width of the parking lane.

- On a three-lane roadway, the spread should be limited to the shoulder width (whether or not it is a parking lane) plus the width of one-half of the driving lane.

- On a four-lane roadway, the spread should be limited to the shoulder width (whether or not it is a parking lane) plus the width of one-half of the outside driving lane.

V−03.03 Design Approach

V−03.03.1 Drainage Patterns

Usually drainage studies are performed on all projects requiring regrading and /or sub-grade improvements, (See Appendix V−03D). Most often the drainage studies are required during the concept phase. On major projects, especially, it becomes necessary to identify drainage patterns, establish corridor responsibilities, and work out any differences with the local government, during this concept phase. The purpose of this is so major decisions on drainage responsibilities between the NDDOT and the City, with respect to funding, can be decided and documented for the permanent record. The policy adopted by the NDDOT concerning this issue follows in the 'City Involvement' section.

V−03.03.2 Inlet Locations

Hydraulic studies require a drainage plan showing the location of inlets with the associated drainage area delineated. The plan should show location of existing or planned utilities such as sanitary sewers, water mains and existing storm drains. General guidelines for inlet placement are as follows:

- Sag point in the gutter grade

- Immediately upstream of median breaks, entrance/exit ramp gores, cross walks and street intersections

- Immediately up - grade of cross slope reversals

- Immediately up - grade from pedestrian cross walks

- At the end of channels in cut sections

- On side streets immediately up - grade from intersections
- Behind curbs, shoulders, or sidewalks to drain low areas

V–03.03.3 Inlets at Underpasses

Removal of surface water in underpasses is critical to prevent flooding. It's removal is primarily dependent upon inlet capacity. Therefore, it's important they remain free of debris. To aid in this effort, Flanking Inlets are recommended on either side of the sag point. (Refer to AASHTO Guidelines for Storm Drain Systems)

V–03.03.4 Inlet Types

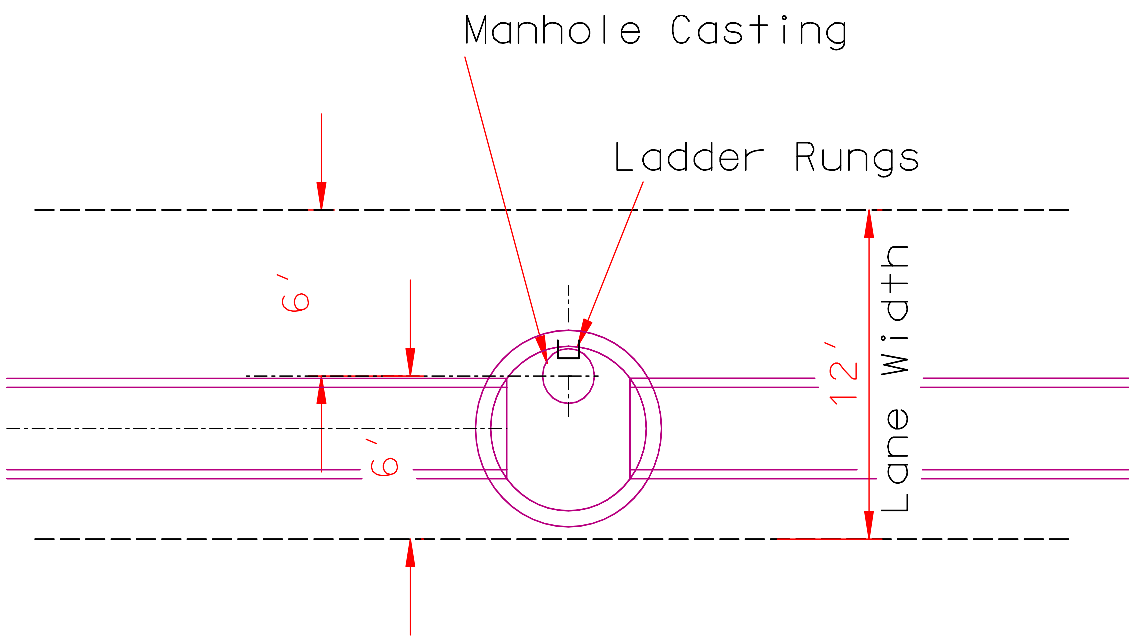
The NDDOT uses the inlet types shown by the Standard Drawings along with a brief description for their prescribed use. These are shown in Appendix V–03E.

V–03.03.5 Manholes Storm Drains

As a rule of thumb manholes are recommended on storm drains wherever the pipe changes direction. Sometimes 7.5 degree bends can be used wherever the distance is short or the drain is not under the roadbed. Manholes used by the NDDOT range from 42" to 120" incremented every 6 inches.

- Standard D-722-5 - Manhole Details - Standard Castings
- Floating Castings are recommended for concrete paved surfaces
- As a rule of thumb, manholes should have a maximum spacing of 400 feet.

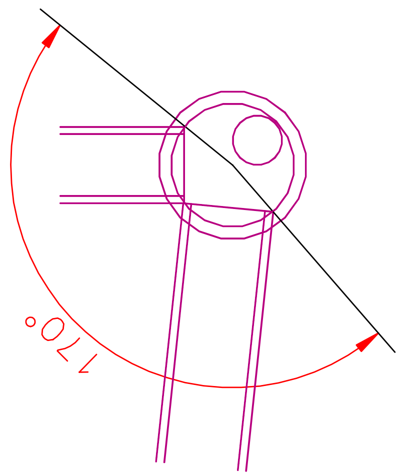
■ Whenever manholes are located under the roadway the covers shall be located such that the



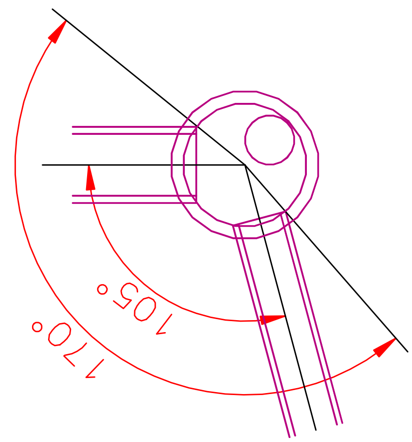
castings are midway between the lane lines.

V–03.03.6 Manhole Knockouts

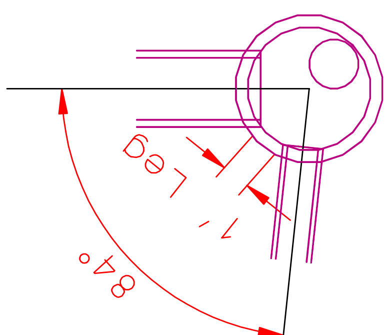
The following guidelines apply to those manholes that are manufactured at the plant and have to be transported to the project site. These guidelines were developed by North Dakota Concrete Products.



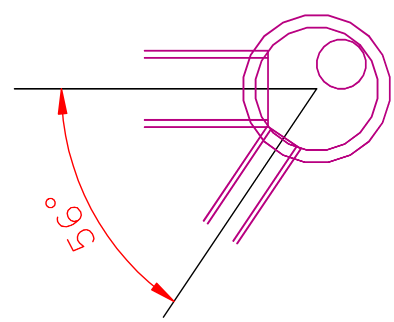
Minimum Angle to Maintain
Minimum Length



Maximum Knockout
Angle - Edge to Edge



Minimum Angle with
No Leg Between



Maximum Knockout
Angle–C. to C.

V–03.03.7 City Participation

The NDDOT has a policy covering this issue which can be found in Appendix V–03F.

V–03.04 Design of Urban Storm Drain

V–03.04.1 Pipe Size and Slope

As the design of each reach of the storm drain depends on the characteristics of the previous reach, the design must start at the upper most part of the drain and proceed downstream a reach at a time. The required capacity of a reach is dependent on it's time of concentration and contributing drainage area. The time of concentration used to determine drain size and slope for a drain is the inlet time at the most remote point, plus the total flow time in the drain. The minimum time of concentration for trunk line design should be 10 minutes for basins with pervious surfaces and 15 minutes for impervious. For inlets the time is 5 minutes for pervious surfaces and 10 minutes for impervious.

The design concentration time for a point below the junction of two or more drain branches is not necessarily the longer of the two periods. A larger flow could easily result with a smaller concentration time. All conditions must be investigated when determining the appropriate time of concentration for any multiple branch storm drain design. The junction of flows from more than one inlet may require a recalculation of discharges, depending upon which time of concentration controls the combined flow.

With the flow in the reach under consideration known, a pipe diameter and slope may be selected to accommodate this flow. When possible, the pipe slope should approximate the roadway slope. In the cities in the Eastern portion of the state this is most often impossible. When the pipe selected for the length and slope of the reach exceeds 0.8 full, the next larger size pipe should be used. The velocity of flow should not be less than 3 ft/sec. The diameter and slope should also be established to fit all control elevations. The design Manning's "n" value for concrete pipe should be .012

With the pipe diameter, slope, and velocity for a reach of pipe known, the invert elevations for each end of the section may be established. It is necessary to analyze the hydraulic grade line of the storm drain system in order to determine if the design flows can be accommodated without water coming out of inlets or manhole access holes.

V–03.04.2 Outfall Design

The purpose of the storm drain outfall is to transport the storm water to a natural drainage watercourse and discharge it with as little erosion and pollution as practicable. A storm drain outfall consists of the outfall line (or channel), possibly a detention basin, and provisions for energy dissipation.

If the storm drain is too deep and no low water discharge elevation available, a pump station will be required. Whenever possible the pump station should provide for a highwater over flow.

Another feature to always evaluate whether or not a lift station is required is the need to detain flows in ditches or prepared basins. This results in smaller pipe sizes, lower costs and reduces downstream impacts.

V–03.04.3 Median Barriers

Median barriers present a special problem for storm drains. Where median barriers are used, particularly on horizontal curves with associated super-elevations, it is necessary to provide for some relief for the water which accumulates against the barrier. This can be done with weep holes in the barrier, although these can become clogged with sanding material & debris. Slotted drains would be a good choice. However, if the drain must be located near the barrier, it may have an impact on the ability of the barrier to perform it's intended function If a slotted drain can be located 5' or more from the barrier, it can be used, and is a good choice for this purpose. If not, the method most often recommended is to use **Type 2** inlets (Appendix V-03 E) with vane grates to intercept the flow into an underground system.

V–03.04.4 Underpasses and Pump Stations

Wherever underpasses are planned the goal should be to minimize the amount of flow into the depressed section, while at the same time providing as much underground storage as possible.

The design requires a higher frequency period for underpasses than for the rest of the roadway. Therefore, additional care is required in underpass design. If the underpass is critical to traffic flow such as interstates, or major highways, design frequencies may be increased to a level commensurate with the flood potential and resulting impacts.

The designer is referred to FHWA's publication " Highway Storm Water Pumping Stations",(FHWA–IP–82–17, Vols. 1&2), for general guidance and information on all aspects of pump station design.

V–03.05 Storm Drain Materials

Generally, Reinforced Concrete Pipe is used for storm drains wherever they cross or parallel the roadway. Other pipe materials are allowable in locations where live loading is not a factor. All of the material allowed is set forth in Section 830 of NDDOT's Standard Specifications For Road and Bridge Construction.

Ductile Iron Sewer Pipe is generally recommended for the discharge pipe of pump stations. Corrugated Polyethylene Pipe should be installed in accordance with Standard Drawing D–714–14.

V–03.06 Bedding and Backfill

V–03.06.1 Pipe Not Under Roadway

Class 3 aggregate should be used in the pipe trench from 4 in. below to the middle of the pipe. From the middle of the pipe to the top of the trench, the backfill should consist of the material that was removed from the trench. Compaction should be ordinary in accordance with Section 203.02 I of the “Standard Specifications for Road and Bridge Construction.”

V–03.06.2 Pipe Under or Within 3 Ft. of The Roadway

Class 3 aggregate should be used from 4 in. below the pipe to the middle of the pipe. From the middle of the pipe to the bottom of the aggregate base, the backfill should consist of the material that was removed from the trench. If the material removed from the trench is unsuitable, Class 3 aggregate may be used to within 3 feet of the aggregate base. The material immediately below the aggregate base should be similar to the material removed from the trench. Compaction should be in accordance with Sec 203.02 I of the Standard Specifications.